The Impact of Resistance Exercise on the Cognitive Function of the Elderly

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ABSTRACT

CASSILHAS, R. C., V. A. R. VIANA, V. GRASSMANN, R. T. SANTOS, R. F. SANTOS, S. TUFIK, and M. T. MELLO. The Impact of Resistance Exercise on the Cognitive Function of the Elderly. *Med. Sci. Sports Exerc.*, Vol. 39, No. 8, pp. 1401–1407, 2007. **Purpose:** The purpose of this study was to assess the impact of 24 wk of resistance training at two different intensities on cognitive functions in the elderly. **Methods:** Sixty-two elderly individuals were randomly assigned to three groups: CONTROL (N = 23), experimental moderate (EMODERATE; N = 19), and experimental high (EHIGH; N = 20). The volunteers were assessed on physical, hemodynamic, cognitive, and mood parameters before and after the program. **Results:** On the 1 RM test (P < 0.001), the two experimental groups performed better than the CONTROL group, but they did not show differences between themselves. The EHIGH group gained more lean mass (P = 0.05) than the CONTROL group and performed better on the following tests: digit span forward (P < 0.001), Corsi's block-tapping task backward (P = 0.001), similarities (P = 0.03), Rey–Osterrieth complex figure immediate recall (P = 0.02), Toulouse–Pieron concentration test errors (P = 0.01), SF-36 (general health) (P = 0.04), POMS (tension–anxiety, P = 0.04; depression–dejection, P = 0.03; and total mood disorder, P = 0.03). The EMODERATE group scored higher means than the CONTROL group on digit span forward (P < 0.001), Corsi's block-tapping task backward (P = 0.01), similarities (P = 0.02), Rey–Osterrieth complex figure immediate recall (P = 0.02), SF-36 (general health, P = 0.005; vitality, P = 0.006), POMS (tension–anxiety, P = 0.001; depression–dejection, P = 0.006; anger–hostility, P = 0.006; fatigue–inertia, P = 0.02; confusion–bewilderment, P = 0.02; and total mood disorder, P = 0.001). We also found that IGF-1 serum levels were higher in the experimental groups (EMODERATE, P = 0.02; EHIGH, P < 0.001). **Conclusions:** Moderate- and high-intensity resistance exercise programs had equally beneficial effects on cognitive functioning. **Key Words:** PHYSICAL ACTIVITY, COGNITION, AGING, OLDER, IGF-1, MOOD

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Aging is a dynamic and progressive process in which morphological, functional, hemodynamic, and psychological changes reduce the individual's ability to adapt to the environment, thus heightening vulnerability to the onset of pathological processes, with muscle mass and strength and eventually diminishing (23).

Similarly, the central nervous system (CNS) and, therefore, cognitive functioning undergoes changes as people grow older. Colcombe et al. (4) reported neuronal loss starting in the third decade of life with a resulting decline in cognitive performance. Additionally, certain cognitive functions seem to be more susceptible to senescence, such as attention, short and long-term memory, and central executive functions (29). These findings are in line with the Kramer and Willis (15) finding that performance tends to decline in relation to processes according to fluid abilities, such as tasks that are learned but not executed.

Many researchers have emphasized the role of physical exercise in retarding or minimizing certain aspects of aging, because it diminishes risk for various chronic diseases and reduces anxiety and depression in the elderly (1). Studies have shown improved cognitive functions in seniors on an aerobic training program (11). However, little is known about the effects of resistance training on these parameters.

Studies have shown that resistance training increases muscular mass and strength in seniors (8) and may also have a positive influence on cognitive performance (19,20).

Different protocols have been used to show the beneficial effect of resistance training on cognitive function. Perrig-Chiello et al. (20) carried out an 8-wk intervention with resistance exercise once a week. Intensity was based on a 15- to 25-repetition maximum (RM) for the trunk muscles and a 12–15 RM for the other muscles. Ozkaya et al. (19) used a different method in relation to the training prescription, but the intervention period was similar (9 wk). They started with intensity at 60% for 1 RM and finished with intensity equivalent to 80% of 1 RM. McDermott and

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Mernitz (17) suggest that this is a high level of intensity and that resistance exercise at 60% of 1 RM might be considered moderate.

These protocols with intensity increments did not allow researchers to evaluate whether the impact on the cognitive function of elderly doing resistance exercise at high intensity alone (80% of 1 RM) differed from that for elderly training at moderate intensity alone (50% of 1 RM). To answer this question from the cognitive standpoint, researchers had to work with separate groups and subject each group to just one level of intensity during the intervention period.

Our own study, therefore, sought to assess the impact of resistance training at two different intensities (50 and 80% of 1 RM) on cognitive functions in the elderly.

METHODS

The study was previously approved by the ethics committee of Federal University of São Paulo under number 0095/03. Participants were 62 male sedentary elderly aged 65–75. Informed consent forms were read and signed by all participants, and they were randomly assigned to three groups: CONTROL (N = 23), experimental moderate (EMODERATE; N = 19), and experimental high (EHIGH; N = 20). The exclusion criteria were the presence of cardiovascular pathologies, preexisting or diagnosed by the clinical evaluation; psychiatric conditions; use of psychotropic drugs; and less than 8 yr of schooling. In addition, we used the Mini-Mental State Examination (MMSE) (10) to exclude individuals with dementia scoring 23 points or less. Volunteers attending less than 75% of the training sessions were also excluded from the study.

Training Protocol

The training protocol consisted of 24 wk of resistance exercise at the center for psychobiology and exercise studies (CEPE). The environment was kept at a temperature of 23 ± 2°C with air humidity 60 ± 2%. Training followed American College of Sports Medicine guidelines on resistance training for seniors (1). Training sessions were held at the same time of day, and exercises targeted the main muscle groups used for everyday activities. We included six exercises on specific equipment (chest press, leg press, vertical traction, abdominal crunch, leg curl, and lower back) manufactured by Technogym. The ACSM (3) recommendations were followed for the exercises and for motivation. Participants worked in twos, one performing the exercise, the other counting the repetitions, taking note of the weights used and repetitions, and correcting breathing and weight-lifting technique.

Experimental Groups

Training for the experimental groups consisted of three 1-h sessions per week. The groups were submitted to a brief 10-min warm-up on the cycloergometer followed by stretching exercises. Loads were 50% of 1 RM for the EMODERATE group and 80% of 1 RM for the EHIGH group. Both groups alternated segments with two series of eight repetitions for each series. Participants rested for 1 min 30 s between series and for 3 min between one apparatus and the next. During the intervention period, both experimental groups remained at the same relative intensity and did not change their percentage on the 1 RM test. As a result, the first 1 RM test was carried out after three sessions for volunteers to become familiar with the minimum load, with overloads of 50 and 80% for the EMODERATE and EHIGH groups, respectively. The 1 RM were repeated for both groups with of overload adjustment, in week 10 and again in weeks 15, 18, and 21.

Control Group

The CONTROL group did not do overload training but did attend sessions at the center (CEPE) once a week to do warm-up and stretching without overload, following the same protocol as the experimental groups (six exercises alternated by segment with two series of eight repetitions, with the same intervals for rest). This CONTROL group model was used to rule out the bias of neuromotor learning and social interaction factors that might mask the real effect of resistance training on the cognitive variables studied.

Testing Protocol

Body composition. Total body mass for the sample was measured using whole-body plethysmography (air-displacement plethysmography, BOD POD body composition system; Life Measurement Instruments, Concord, CA) as described in the user's manual, in addition to those in the studies of Fields and Hunter (9). We determined lean- and fat-mass compositions. Height was measured by a stadiometer manufactured by Sanny. Body mass index (BMI) was calculated as total body mass divided by height squared.

1 RM test. We used recommendations for the 1 RM test proposed by Kraemer et al. (14) to obtain the training overload for all six apparatuses. 1 RM tests were carried out at the same time of day as the training sessions. Before doing the 1 RM test, the groups had three sessions to become familiar with the apparatus at minimum load. The 1 RM test protocol consisted of a 5-min warm-up on a cycloergometer followed by stretching exercises, then two series with eight repetitions on the test apparatus, the first with a light load and the second with a heavy one, then the first attempt at the test increasing load until the maximum was obtained in one repetition. There were at most three subsequent attempts at 3-min intervals. The examiner constantly encouraged the volunteers. We also made a point of keeping the same professional at the same apparatus during the pre- and postintervention evaluations.

Neuropsychological tests. The neuropsychological tests were administered in a single session, and none lasted more than an hour. The testing room had a controlled

TABLE 1. Descriptive analysis of the variables.

	Preintervention Values			Experimental Moderate vs Control	Experimental High vs Control	Experimental Moderate vs Experimental High
	Control (*N* = 23)	Experimental Moderate (*N* = 19)	Experimental High (*N* = 20)	*P*	*P*	*P*
Age (yr)	67.04 ± 0.54	69.01 ± 1.10	68.4 ± 0.67	0.07	0.22	0.16
Height (m)	1.68 ± 0.02	1.70 ± 0.01	1.70 ± 0.02	0.42	0.39	0.99
Total body mass (kg)	76.44 ± 2.81	80.23 ± 3.00	76.61 ± 2.12	0.35	0.96	0.34
BMI ($kg \cdot m^{-2}$)	26.83 ± 0.70	27.61 ± 0.87	26.48 ± 0.64	0.45	0.70	0.29
Lean mass (kg)	53.80 ± 1.67	55.28 ± 1.61	54.84 ± 0.84	0.50	0.62	0.83
Fat mass (%)	28.98 ± 1.49	30.38 ± 1.74	27.68 ± 1.68	0.54	0.57	0.27

Values of preintervention period.
* $P < 0.05$. ANOVA one-way test values expressed as mean ± SE.

environment, with the temperature kept at 23 ± 2°C and air humidity at 60 ± 2%. All volunteers were evaluated in the morning (from 8 to 11 a.m.) by the same examiner. The same time of day was scheduled for evaluation and reevaluation, to minimize circadian variations.

The neuropsychological assessment comprised the following tests: Wechsler Adult Intelligence Scale III (WAIS III) (similarities: assessing central executive/digit span, forward and backward: assessing short-term memory) (25); Wechsler Memory Scale–Revised (WSM-R) (Corsi's block-tapping task, forward and backward: assessing visual modality of short-term memory) (25); Toulouse–Pieron's concentration attention test: assessing attention (22); and Rey–Osterrieth complex figure (form A–Rey figure and form B–Taylor alternative version), assessing long-term episodic memory (25).

Quality of life and mood profile. We used the Medical Outcomes Study SF-36 questionnaire (6) to assess quality of life of the sample. The Geriatric Depression Scale (GDS) was used to measure depression (30). To evaluate mood state, we used the profile of mood states (POMS) (18). These instruments were administered at the same time of day as the evaluation and reevaluation of each volunteer (8 to 11 a.m.).

Hemodynamic measures. Volunteers fasted for 8 h overnight, and a sample of preprandial venous blood was collected in the morning (8–8:30 a.m.). From those samples we measured blood plasma and concentrations of erythrocytes and hematocrits.

Blood viscosity. Blood viscosity was measured using a viscosimeter (DV-III Brookfield Engineering Labs. Inc., Stoughton, MA), which is an axis and rotational system dipped in a recipient containing the blood to be measured. The resistance of the fluid submitted to a rotation of 30 rpm yields a measure that is proportional to its viscosity, and the reading is shown on a digital display.

Erythrocytes and hematocrits. Concentrations of erythrocytes and hematocrits were measured by the flow cytometry method using a CBC TIPEMAC kit with an ADVIA 120 model manufactured by Bayer.

Insulin-like growth factor-1. Insulin-like growth factor-1 IGF-1 serum concentration was determined using an immunoradiometric assay kit (DSL-5600) manufactured by Diagnostics Systems Laboratories (DSL), and a Gamma Counter model C12, manufactured by Diagnostic Products Corporation (DPC) for the quantitative analysis of gamma radioactivity.

Statistical Analysis

The Statistica version 6.1 program was used for analysis of variables of body composition, 1 RM tests, neuropsychological tests, quality of life and mood profile, and hemodynamic measures. One-way ANOVA with Duncan's *post hoc* test was used to determine the homogeneity of the descriptive variables of the groups studied in the preintervention period. To assess differences between the groups, we used the ANCOVA test, with Duncan's *post hoc* test with the delta means (postintervention − preintervention = delta means) and covariated the preintervention values of each variable studied. ANCOVA was chosen to eliminate any effect of relation between the variables and their preintervention values.

RESULTS

Training session attendance was above 75% for all volunteers, and nobody dropped out. No significant differences were detected across groups for the variables in the

TABLE 2. Body composition.

	Change (post − pre)			Experimental Moderate vs Control	Experimental High vs Control	Experimental Moderate vs Experimental High
	Control (*N* = 23)	Experimental Moderate (*N* = 19)	Experimental High (*N* = 20)	*P*	*P*	*P*
Height (m)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.69	0.41	0.25
Total body mass (kg)	−0.63 ± 0.49	−0.23 ± 0.36	−0.36 ± 0.61	0.86	0.73	0.63
BMI ($kg \cdot m^{-2}$)	−0.16 ± 0.15	−0.04 ± 0.25	−0.05 ± 0.22	0.70	0.70	0.97
Lean mass (kg)	−1.11 ± 0.52	−1.13 ± 0.56	0.24 ± 0.39	0.97	0.05*	0.06
Fat mass (%)	0.98 ± 0.71	1.25 ± 0.81	−0.51 ± 0.51	0.76	0.10	0.06

* $P < 0.05$. ANCOVA test values expressed as mean change ± SE.

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TABLE 3. One-repetition maximum tests.

	Change (post − pre)			Experimental Moderate vs Control	Experimental High vs Control	Experimental Moderate vs Experimental High
	Control (*N* = 23)	Experimental Moderate (*N* = 19)	Experimental High (*N* = 20)	*P*	*P*	*P*
Chest press	1.08 ± 2.26	25.52 ± 4.13	31.75 ± 2.69	<0.001*	<0.001*	0.25
Leg press	−13.91 ± 10.62	94.73 ± 10.24	127.00 ± 15.78	<0.001*	<0.001*	0.67
Vertical traction	−25.87 ± 17.27	46.05 ± 4.28	50.00 ± 5.73	<0.001*	<0.001*	0.85
Abdominal crunch	10.21 ± 2.12	23.68 ± 2.83	30.00 ± 3.36	<0.001*	<0.001*	0.82
Leg curl	−2.39 ± 2.45	28.68 ± 3.35	34.75 ± 3.61	<0.001*	<0.001*	0.87
Lower back	3.04 ± 1.49	27.10 ± 4.26	39.75 ± 4.60	<0.001*	<0.001*	0.28

* $P < 0.05$. ANCOVA test values expressed as mean change ± SE.

preintervention period. Table 1 shows the descriptive variables of the sample. Therefore, statistically speaking, the three groups were similar at the beginning of the study. However, we did observe a higher increase in lean mass of the EHIGH group in relation to the CONTROL group (P = 0.05) (Table 2). No significant alterations were observed in the other body composition variables (Table 2).

As Table 3 shows, 1 RM test scores for the groups studied (delta means for the EMODERATE and EHIGH groups) were statistically higher than those of the CONTROL ($P < 0.001$) on all tests.

Neuropsychological test scores are shown in Table 4. The EMODERATE group presented higher delta means than the CONTROL group for the following tests: digit span forward ($P < 0.001$), Corsi's block-tapping task backward (P = 0.01), similarities (P = 0.02), and Rey–Osterrieth complex figure immediate recall (P = 0.02) (Table 4). The results were similar for the EHIGH group, which showed higher delta means than the CONTROL group for digit span forward ($P < 0.001$), Corsi's block-tapping task backward (P = 0.001), similarities (P = 0.03), and Rey–Osterrieth complex figure immediate recall (P = 0.02) (Table 4). Again, EMODERATE delta means for Toulouse–Pieron test item errors (P = 0.01) were lower than those of the CONTROL group (Table 4). No differences were detected across groups for the other variables (Table 4).

The sample's mood profile and quality-of-life assessment are shown in Table 5. In relation to the SF-36 questionnaire, the EMODERATE group showed significant improvement in the delta means on general health (P = 0.005) and vitality (P = 0.006), whereas EHIGH showed improvement only in relation to the general health domain (P = 0.04). As for the POMS questionnaire, the EMODERATE group showed greater improvement of the delta means than the CONTROL group in relation to the mood factors tension–anxiety (P = 0.001), depression–dejection (P = 0.006), anger–hostility (P = 0.006), fatigue–inertia (P = 0.02), confusion–bewilderment (P = 0.02), and total mood disorder (P = 0.001). The EHIGH group also presented improvement in the delta means of some domains of the POMS in relation to the CONTROL group, such as tension–anxiety (P = 0.04), depression–dejection (P = 0.03), and total mood disorder (P = 0.03) (Table 5). No differences in relation to the other aspects evaluated were detected between the groups after the intervention (Table 5).

The sample's hemodynamic *measures* did not show statistically significant differences for the variables studied (Table 6).

Table 7 shows the IGF-1 serum concentration after intervention. We found higher IGF-1 in both experimental groups (EMODERATE, P = 0.02; EHIGH, $P < 0.001$) in relation to the CONTROL group.

DISCUSSION

The consensus view is that physical exercise benefits the health of the elderly by reducing the risk of developing

TABLE 4. Neuropsychological tests.

	Change (post − pre)			Experimental Moderate vs Control	Experimental High vs Control	Experimental Moderate vs Experimental High
	Control (*N* = 23)	Experimental Moderate (*N* = 19)	Experimental High (*N* = 20)	*P*	*P*	*P*
Digit span (score)						
Forward	−0.47 ± 0.19	0.51 ± 0.20	0.50 ± 0.19	<0.001*	<0.001*	0.78
Backward	−0.14 ± 0.18	−0.12 ± 0.17	−0.10 ± 0.19	0.18	0.20	0.10
Corsis block-tapping (score)						
Forward	0.18 ± 0.24	0.29 ± 0.20	0.30 ± 0.23	0.87	0.25	0.22
Backward	0.0 ± 0.24	0.97 ± 0.25	0.95 ± 0.22	0.01*	0.001*	0.30
Similarities (score)	−2.75 ± 0.18	1.08 ± 1.32	1.05 ± 1.45	0.02*	0.08*	0.82
Toulouse–Pieron (score)						
Cancellations numbers	6.67 ± 3.48	4.85 ± 6.27	6.90 ± 5.69	0.17	0.32	0.11
Errors	5.52 ± 1.40	0.15 ± 0.22	−4.85 ± 6.27	0.28	0.01*	0.10
Rey Osterrieth figure (score)						
Copy	6.10 ± 1.28	6.45 ± 0.90	6.45 ± 0.89	0.18	0.54	0.41
Immediate recall	5.17 ± 0.98	8.38 ± 1.26	8.31 ± 1.22	0.02*	0.02*	0.28

* $P < 0.05$. ANCOVA test values expressed as mean change ± SE.

TABLE 5. Mood profile and quality of life.

	Change (post − pre)			Experimental Moderate vs Control	Experimental High vs Control	Experimental Moderate vs Experimental High
	Control (*N* = 23)	Experimental Moderate (*N* = 19)	Experimental High (*N* = 20)	*P*	*P*	*P*
SF (score)						
Mean	−6.03 ± 4.08	0.76 ± 2.40	1.31 ± 20.03	0.11	0.10	0.89
Physical function	1.95 ± 2.60	3.94 ± 2.87	3.25 ± 2.87	0.48	0.62	0.79
Role-physical	−16.30 ± 9.11	−7.89 ± 8.56	0.00 ± 6.01	0.36	0.11	0.42
Bodily pain	−6.30 ± 6.70	−5.00 ± 6.44	−2.15 ± 3.30	0.82	0.5	0.62
General health	−4.34 ± 3.36	−8.94 ± 4.98	−5.00 ± 2.07	0.005*	0.04*	0.36
Vitality	−6.08 ± 4.51	−6.84 ± 3.77	−1.00 ± 2.13	0.006*	0.24	0.09
Social function	−7.60 ± 7.40	−4.60 ± 3.34	3.12 ± 3.49	0.60	0.09	0.20
Role—emotional	−8.69 ± 8.43	−8.77 ± 5.60	3.33 ± 4.77	0.99	0.58	0.59
Mental health	−0.87 ± 4.10	7.36 ± 3.28	5.60 ± 2.83	0.06	0.13	0.66
GDS (score)	0.00 ± 0.73	−1.47 ± 0.62	−0.75 ± 0.52	0.11	0.39	0.41
POMS (score)						
Tension–anxiety	3.00 ± 1.03	−1.68 ± 0.87	0.20 ± 1.08	0.001*	0.04*	0.17
Depression–dejection	2.60 ± 1.69	−1.89 ± 0.85	−0.70 ± 0.78	0.006*	0.03*	0.43
Anger–hostility	2.73 ± 1.68	−2.68 ± 1.03	0.65 ± 1.24	0.006*	0.25	0.07
Vigor–activity	1.21 ± 1.17	3.84 ± 1.10	2.90 ± 0.98	0.10	0.26	0.53
Fatigue–inertia	1.52 ± 0.70	−0.31 ± 0.50	0.30 ± 0.43	0.02*	0.10	0.40
Confusion–bewilderment	1.13 ± 0.83	−0.84 ± 0.38	−0.40 ± 0.53	0.02*	0.06	0.59
Total mood disorder	10.69 ± 5.90	−11.26 ± 3.01	−2.85 ± 3.31	0.001*	0.03*	0.17

* $P < 0.05$. ANCOVA test values expressed as mean change ± SE.

various chronic diseases, in addition to improving physical and mental fitness. However, different types of physical exercise have different effects and may entail different levels of improvement, depending on the relation between volume and intensity. This is the case for resistance exercise in the elderly, which is associated with increased muscle strength and mass (8).

In this respect, our study corroborates previous findings in that we observed improvement in all 1 RM tests for both groups compared with the CONTROL group, with unmistakable muscle strength gain after intervention. On the other hand, we found an increase in lean mass in relation to the CONTROL group only in the EHIGH group. These results match those of Fiatarone et al. (8), who observed considerable gains in muscle strength and lean mass in elderly doing high-intensity resistance training.

Nevertheless, no statistically significant differences were detected between the muscle strength increases of the experimental groups and certain equipment items. Even though the groups trained at different intensities, the impact on their muscle strength gain was similar. As opposed to these findings, Kalapotharakos et al. (13) compared the muscle strength of elderly individuals doing resistance exercise at different intensities (moderate and high) for 12 wk and found that both groups improved in relation to the control group, although the group that trained at high intensity showed a significantly greater improvement in relation to the moderate-intensity group. However, Tsutsumi et al. (27) have observed that elderly women who underwent 12 wk of resistance training at moderate and high intensity improved their muscle strength in similar ways.

The same study found that both groups (moderate intensity and high intensity) improved their mood profile in relation to the control group, but the moderate-intensity group showed a sharper improvement than did the high-intensity one. Similar findings emerged from our study, because both experimental groups had better mood profile and quality-of-life scores than did the CONTROL group. There was also stronger impact on the mood profile of the EMODERATE than the EHIGH group, which suggests that moderate-intensity exercise is more effective than high-intensity exercise for improving mood in the elderly. This may be attributable to the fact that mood is associated with certain aspects of cognitive functions in the elderly, and high depression scores in this population are associated with diminished cognitive performance. Therefore, as the mood profile improves, so does the cognitive function (2).

Epidemiological studies suggest that physical exercise improves the CNS and, thus, cognitive functions in the elderly. Epidemiological data suggest that moderately active individuals are at less risk of developing mental disorders than sedentary ones (28).

Perrig-Chiello et al. (20) had 46 elderly volunteers take an 8-wk resistance exercise program, which resulted in

TABLE 6. Hemodynamic analysis.

	Change (post − pre)			Experimental Moderate vs Control	Experimental High vs Control	Experimental Moderate vs Experimental High
	Control (*N* = 23)	Experimental Moderate (*N* = 19)	Experimental High (*N* = 20)	*P*	*P*	*P*
Blood viscosity (mPa)	0.05 ± 0.31	−0.42 ± 0.19	−0.12 ± 0.27	0.18	0.60	0.38
Erythrocytes (M·mm^{-2})	−0.11 ± 0.07	−0.08 ± 0.05	−0.03 ± 0.04	0.24	0.24	0.97
Hematocrit (%)	0.55 ± 0.12	0.65 ± 0.60	0.07 ± 0.51	0.40	0.10	0.56

* $P < 0.05$. ANCOVA test values expressed as mean change ± SE.

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TABLE 7. Insulin-like growth factor-1 (IGF-1) analysis.

	Change (post − pre)			Experimental Moderate vs Control	Experimental High vs Control	Experimental Moderate vs Experimental High
	Control (N = 23)	Experimental Moderate (N = 19)	Experimental High (N = 20)	P	P	P
IGF-1 (ng·mL^{-1})	−25.40 ± 25.71	41.12 ± 22.56	80.73 ± 22.31	0.02*	<0.001*	0.15

* $P < 0.05$. ANCOVA test values expressed as mean change ± SE.

improved psychological well-being and cognitive functioning. In another study carried out recently, Ozkaya et al. (19) had 36 volunteers aged 60–85 do 9 wk of physical exercise. Both exercise groups (strength training and endurance training) improved their cognitive function in relation to the control group, with no statistically significant differences between them (aerobic and resistance), which shows that either type can improve cognitive performance.

Our study confirmed previous findings on the improvement of cognitive performance in elderly subjected to resistance training. We found more improvement in the performance of the experimental groups after the intervention with resistance exercise compared with the CONTROL group on the following tests: digit span forward, Corsi's block-tapping task backward, similarities, and Rey–Osterrieth complex figure immediate recall. Only for the EHIGH group were errors in the Toulouse–Pieron test reduced. This better performance of the groups after the period of intervention suggests an improvement in short- and long-term memories, with better functioning of the central executive, in addition to a significant improvement in attention and lower neglect. However, no statistically significant differences were detected in the comparison of the two experimental groups. From the cognitive standpoint, this result shows that both intensities made a similar contribution to enhanced cognitive performance in the elderly.

Certain mechanisms were associated with the positive impact of resistance exercise on the cognitive function of the elderly observed in our own study and previous research (19,20). Better blood flow in the brain results from a series of hemodynamic alterations facilitating the transportation of nutrients and oxygen to critical CNS structures related to learning and memory, thus improving cognitive function. Santos et al. (24) found that increased blood viscosity was negatively correlated with cognitive performance, indicating impairment of cognitive function in young and elderly individuals subjected to neuropsychological, blood viscosity, and single photon emission computed tomography tests. The results showed a global reduction in cognitive function with aging; higher blood viscosity contributed to this and correlated with cognitive impairments and reductions in brain perfusion.

In fact, the hypothesis of improved cognitive performance being attributable to improved blood flow in the brain from lower blood viscosity seems quite appropriate for elderly on aerobic training programs, because the latter are known to lead to better blood flow in many structures. Blood flow can be measured globally by analyzing blood viscosity, which reflects the facility of blood flow parameters in the vascular system. The main determinants of blood viscosity are hematocrit and erythrocyte concentrations (7).

However, this hypothesis does not seem to be applicable to our study, because the hemodynamic measures evaluated (blood viscosity, erythrocytes, and hematocrits) were unchanged after intervention, which leads us to believe that different mechanisms are triggered depending on the type of exercise. Growth factors such as IGF-1 might be intermediaries for the effects of resistance training at central levels, reflecting an improvement in the cognitive function in the elderly.

Our study found a significant increase in IGF-1 serum concentrations and improved cognitive function in both groups; compared with the controls, the serum has been associated with cognitive processes. Statistically important correlations were obtained between the peripheral concentrations of IGF-1 and cognitive performance, especially in the elderly, so higher concentrations might account for improved cognitive function after resistance exercise. Moreover, higher levels of IGF-1 serum have been reported in elderly doing resistance training (3), possibly because of its being transported to the CNS via the hematoencephalic barrier, triggering better cognition through various central mechanisms (26).

Cotman and Berchtold (5) and Kramer and Willis (15) have shown direct and indirect interaction mechanisms between IGF-1 and certain CNS molecules. There is IGF-1 involvement in modulation of the brain-derived neurotrophic factor (BDNF) molecule; the latter acts on several CNS areas, being responsible for maintenance of basal prosencephalon, striatum, hippocampus, cortex, septum neurons, and cerebellar and motor neurons related to cognitive processes (16). Neuronal activity seems to be involved with IGF-1 through a positive association with increased numbers of c-Fos cells in neurons, eliciting neuronal activation.

Clinical and basic studies with experimental designs encompassing resistance exercise, central and periphery IGF-1 levels and cognitive testing are required to shed light on IGF-1 involvement in this whole process. Although there are other ways of attempting to explain how resistance exercise improves the cognitive function, we should not ignore the existence of other mechanisms, and we should not be restricted to the idea that there might be only one intermediary, because physical exercise influences various aspects. As in the oxidative stress of the CNS, exercise could boost activity of antioxidant enzymes as in skeletal muscle, enhancing defense against damage caused by oxygen-reactive specimens (21). These alterations may, in the long run, modify the functioning of central systems, particularly the hippocampus, amygdala, medial septum, and entorhinal cortex (important regions related to mnemonic processes such as consolidation, storage, and recall) (12).

This study has shown that resistance exercise had a positive impact on cognitive function in the elderly. The beneficial effects did not depend on the resistance exercise being performed at moderate or high levels of intensity. From the psychological standpoint, however, moderate intensity might be more appropriate for the elderly because it provided more significant improvements in their mood profiles and certain aspects of quality of life, in addition to the cognitive benefits.

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